ScotFarm – a farm level optimising model

Shailesh Shrestha

Policy Analysis, Behaviour and Innovation Team (PABIT)
Land economy, environment and society research group
Scotland’s Rural College (SRUC)
# Table of Contents

Introduction .......................................................................................................................... 4

Model structure: .................................................................................................................... 4

  Model basic assumptions: ................................................................................................. 4

  Model dynamics ................................................................................................................. 5

Model components: .............................................................................................................. 6

  Livestock .......................................................................................................................... 7

  Crop system: .................................................................................................................... 10

Farm resources .................................................................................................................... 13

Price projections .................................................................................................................. 17

Farm margins ....................................................................................................................... 18

Farm profits (Objective Function) ...................................................................................... 19

Appendix ........................................................................................................................... 20
Figure 1: The modelling procedure ................................................................. 5
Figure 2: A schematic structure of the ScotFarm model ...................................... 7
Figure 3: Livestock module ............................................................................. 7
Figure 4: The crop module ............................................................................ 11
Figure 5: A schematic diagram of SPACSYS ..................................................... 12
Figure 6: A snippet of feed requirement module .............................................. 15
**Introduction**

ScotFarm is a dynamic linear programming (LP) model which optimises farm margins within a number of limiting farm resources. The model was developed at SRUC in 2012 in view to conduct impact assessment of CAP reforms on Scottish farms. Earlier versions of the model have been used in a number of farm level analyses of English dairy farms (Shrestha, 2004) and Irish livestock and crop farms (Shrestha 2006, 2007, 2008; Hennessy et al., 2008). The model is based on farming system analysis where all existing farm activities are inter linked (both in physical and financial aspects) and contribute to the optimal objective function that is maximising farm profit. The farm profit comprised of the accumulated revenues collected from the final product of the farm activities (i.e. crops, animals and milk) plus farm payments minus costs incurred for inputs under those activities. The input costs were replacement costs for livestock, variable costs including labour, feed (excluding grazing) and veterinary costs and overhead costs on farms. The model assumes that all farmers are profit oriented.

**Modelling software:** The ScotFarm is written and solved in GAMS (General Algebraic Modelling Systems) using CONOPT solver.

**Data requirement:** The model is based on farming system analysis so requires data that represents all farm activities and both qualitative and quantitative linkage between them. A good data set to run the model is the one which provides both physical and financial data for a farm. A good example of data source is the Scottish Farm Accountancy Survey (FAS) which is equivalent to FADN (Farm Accountancy Data Network) that is collected across EU member states. Similar data such as Farm Business Survey (FBS) in England and National Farm Survey (NFS) in Ireland had been used in the model in the past. Besides farm level data, a number of coefficients, parameters and price information are taken from the literatures (such as Farm Management Handbook), expert knowledge and online market reports (such as QMC market reports).

**Model structure:**

Model basic assumptions:

The fundamental assumption of the model is that all farmers are profit maximising and use farm resources in optimum way to maximise farm profit. The farm profit is determined by the revenues collected under farm activities plus farm support payments minus variable costs associated with the farm activities, when gross margin is used as a measure of profit, and overhead costs when net margin is calculated. The farm variable and overhead costs are taken from the farm survey data and included following costs.

---

1. The overhead costs are only included the model is used to determine farm net margins.
2. https://gams.com/
6. http://www.farmbusinesssurvey.co.uk/
8. https://www.sruc.ac.uk/info/120376/farm_management_handbook
**Variable costs** = total variable costs (that includes veterinary and medicine, artificial insemination (AI), disinfectant, detergents, branding, bull hire, marketing, disposal of waste, litter, contract (shearing, dipping etc.); crop expenses including seeds, fertilizers, lime, sprays, contract, irrigation and sundry including production, storage, marketing, levy, inspection charges, boxing)

**overheads** = Fixed costs (includes machinery, electricity, contract for maintenance, machinery repairs, leasing charges, building repairs, rent, council tax, fuel, water, insurance, taxes, services, telephone, VAT, interests)

For yield from grassland, the model uses following assumptions:

**Grassland = Permanent grassland**\(^9\) (100% yield) + temporary grassland\(^{10}\) (100% yield) + rough grazing (25% yield)

**Model dynamics**

The model is dynamic in a sense that it runs for a number of years and optimises farm profits over that time period. The model is not recursive as it is not executed each year. Although farm activities on a particular farm are based on the activities in the previous year, the decision on farm activities on each year is based on the final optimisation process that takes account of all years the model is running. The outcome of the multiple years is then averaged to provide final results of the model. The model provides a counterfactual comparison between different farm conditions and hence a useful tool in impact assessments of for instant policy reforms.

![Figure 1: The modelling procedure](image)

**Justification of approach**

A dynamic LP model, however, has starting and terminal effects that may influence the model results (Ahmad, 1997). The starting effect is due to the model’s characteristics of using farm

---

\(^9\) Permanent grassland cannot be transferred to arable crops less than 5 years

\(^{10}\) Temporary grassland can be transferred to arable crops any time if needed by the model
resources as optimal levels and hence adjusting the management practises under modelling conditions. The starting effect can be minimised as much as possible by calibrating the model for year 1 and restricting the model to optimise farm margin based on management and resource efficiencies (such as using technological efficiency weightings). The terminal effect makes the model avoid putting inputs on farms and starts offloading farm products to increase farm revenues. This is the case when no restrictions are in place on the final year of the model run. For example, for a beef farm, if there is not restriction on minimum number of animals that should be kept on farm, all beef animals on final year will be sold to maximise farm profits. Providing a minimum number of beef animals would remove this limitation of LP modelling. However, this would put an additional constraint on model which reduces decision making flexibility on farms. An alternative way is to remove results from certain numbers of initial and final years (3-4 years each way) and use the results in the middle part of the model as shown in Figure 1. This will leave the results from the years which are not biased with the starting and terminal effects of LP modelling. The ScotFarm uses this technique to minimise starting and final year effects in the results. For instance, the model runs of farm level data for a number of years (15 years in this case), and providing outputs for each year as shown is Figure 1. The outputs from middle 8 years are then averaged out to provide the farm results under that particular farming condition.

**Model components:**
The structure of the model is presented in a schematic diagram provided in Figure 2. It consists of four components; dairy, beef, sheep and arable production systems. These systems were constrained by land, labour, feed and stock replacement available to a farm. The total land available to a farm is fixed however farms are allowed to transfer land between different production systems and also re-allocate land to different crop systems. Farms were also allowed to buy in feeds, animal replacements and hire labour if required.
Livestock
The model contains a livestock component which covers all three common livestock production systems in Scotland; dairy, beef and sheep systems. Each of the livestock system uses farm resources and previous year’s animal numbers to determine the number of animals kept on farm on a particular year.

Assumptions related to livestock module:

i. All existing activities are available to a farm
ii. All farm animals on a farm have similar production level (one milk yield level, final weight etc.) based on farm level data
iii. Livestock are on optimum feed regime
iv. Mortality rate constant for all farms and all over the years
v. 50% calves born are female
vi. Production level stays the same with all combination of feeds as long as energy and protein requirements are maintained.

The animal numbers on farm is first set up to the number provided from farm level dataset for the base year, such as described below:
**Data initialisation**

Starting point where animal numbers \((\text{totani})\) are restricted to the numbers from farm level data input \((\text{ANI})\). The number of animals on farms is constrained over an optimal stocking rate and a threshold of maximum number. This is to limit the number of animal to a farm’s holding capacity. An optimal stocking rate ensures quality of the grazing land and threshold of certain animal number ensures the number of animals within the holding capacity of the farm such as buildings and milk storage capacity for dairy farms. Farms can however increase animal numbers by increasing farm resources such as renting in land, increasing storage capacity etc.

The dairy system has a four year replacement structure where dairy animals are culled after every four year. Similarly beef and sheep systems followed a two year replacement structure. The animals were replaced by on-farm or off-farm replacement stocks.

\[\text{totani}(f,a,t1) = \text{ANI}(f,a)\]

Number of animals on farm is restricted to a threshold ‘\(X\)’ times the numbers in the farm level input data. ‘\(X\)’ depends on the holding capacity of a farm.

\[\text{totani}(f,a,t) \leq \text{ANI}(f,a) \times X\]

**Beef system**

There are four categories of beef animals in the model; suckler (‘asc’), calf (‘asc6’), 1 year old beef (‘abl’) and 2 year old beef (‘ab2’). The system in the model has three activities; suckler, rearer and finisher activities. The model selects these activities based on the starting number of the animals and management practices represented in the farm level data. For example if there are no suckler beef on farm in the starting year, the model will not select suckler activity during the model runs.

**Animal dynamics**

The number of animals in each category is determined by the number of animals in the previous year and buying and selling activities in the current year. Suckler beef numbers (‘asc’) are maintained on farms based on suckler numbers in the previous year. They are regularly replaced by culling and buying. The number can change each year by the model. Calf (‘asc6’) number equals to number of sucklers and calving and survival rates. Any beef number after 1st year is the number of the animals in the previous year plus numbers of animals bought minus number of animals sold that year.

\[\text{totani}(f,'asc',y) = \text{totani}(f,'asc',y-1) + \text{buysuck}(f,y) - \text{cullsuck}(f,y-1)\]
\[\text{totani}(f,'asc6',y) = \text{totani}(f,'asc',y) \times \text{calrate} \times \text{survrate}\]
\[\text{totani}(f,'abl',y) = \text{totani}(f,'asc6',y-1) - \text{sellcalf}(f,y-1) + \text{buybeef1}(f,y)\]
\[\text{totani}(f,'ab2',y) = \text{totani}(f,'abl',y-1) - \text{sellbeef1}(f,y-1)\]

\(^{11}\) All model subscrips are defined in the Index section
**Activities and conditions**

Beef activities are restricted by following conditions. The number of 1-year old beef animals sold \((sellbeef1)\) should be less than total year 1 beef animals on farm. All beef animals are sold when they reach 2 years of age \((sellbeef2)\). Sold calf numbers should be less than or equal to the total number of calves on farm.

\[
sellbeef1(f,y) \leq \text{totani}(f,\text{ab1},y);
\]
\[
sellbeef2(f,y) = \text{totani}(f,\text{ab2},y);
\]
\[
sellcalf(f,y) \leq \text{totani}(f,\text{asc6},y);
\]

The suckler replacement cycle is assumed to be 8 years so that 12.5% of suckler cows are replaced each year. The number of replacement suckler cannot be more that the number of culled suckler cows.

\[
cullsuck(f,y) = \text{totani}(f,\text{asc},y) \times 0.125
\]
\[
\text{buysuck}(f,y) \leq \text{cullsuck}(f,y)
\]

**Dairy system**

The dairy system in the model assumes an average milk yield based on farm data for all animals on farm. The system is assumed to follow 4 years of lactation cycle which means once start lactating, the animals are kept till their fourth lactation.

**Animal dynamics**

Dairy female calves \(\text{('ac')}\) are 50% of calves born to the dairy cows \(\text{('ad')}\) based on fixed calving and survival rates. Rest of the calves are assumed to be male and sold immediately.

\[
\text{totani}(f,\text{ac},y) = \text{totani}(f,\text{ad},y) \times \text{calrate} \times 0.5 \times \text{survrate}
\]

Dairy heifers \(\text{('ah')}\) in a particular year \(\text{('y')}\) are the number of calves in previous year and any heifers bought in that year. Bought heifer number is based on the numbers of the sold (culled) dairy animals. Similarly, dairy numbers is the summation of number of dairy animals and heifers minus the number of culled animals in the previous year. Dairy cycle is assumed to be 4 years so every year dairy animals are culled by 1/4\(^{th}\) of the total dairy animals on farm.

\[
\text{totani}(f,\text{ah},y) = \text{totani}(f,\text{ac},y-1) + \text{buyheif}(f,y)
\]
\[
\text{totani}(f,\text{ad},y) = \text{totani}(f,\text{ad},y-1) + \text{totani}(f,\text{ah},y-1) - \text{culldairy}(f,y-1);
\]

**Activities and conditions**

A quarter of lactating dairy animals is culled \(\text{culldairy}\) each year to follow 4-year lactation cycle and is replaced by on-farm heifers and heifers bought in from the market \(\text{buyheif}\) bought in. Total milk production is the summation of milk produced by all lactating cows and assumed to be sold in the market. There is no consideration for spillage and own consumption.
culldairy(f,y) = totani(f,'ad',y) * 0.25

buyheif(f,y) ≤ culldairy(f,y-1)

totmilk(f,y) = \sum_{t} totani(f,"ad",y) * MILKIELD(f)

Sheep system

The number of lamb ('al') in each year is based on number of ewe ('ae'), a pre-set lambing and survival rates minus any number of lambs sold that year. Number of sold lamb is constrained over the number of lamb kept on farm. The number of ewe in each year is based on number of ewe the previous year plus any replacement buy the previous year minus number of ewe culled. A condition was set that a farm cannot buy replacement ewe if do not have a sheep system in first year. The replacement (buylamb) is restricted to 4 year production cycle and replacement number is also constrained over the culled ewe.

totani(f,'al',y) = totani(f,'ae',y)*Lambrate*survrate - selllamb(f,y)

totani(f,'ae',y) = totani(f,'ae',y-1)- sellewe(f,y) + buylamb(f,y-1)*ANI(f,'ae')

Activities and conditions

All lambs are sold within first year of their lives. The culled ewe (sellewe) number is restricted to 25% of total ewe number each year. This is based on assumption of 4 year replacement cycle. Finally, the number of replacement should be equal or less than total number of culled ewe.

selllamb(f,y) ≤ totani(f,'al',y)

sellewe(f,y) = totani(f,'ae',y)*0.25

buylamb(f,y) ≤ sellewe(f,y)

Crop system:

The crop system in the model is constrained over margins generated by each crops. The current version of the model does not take in detailed management practices such as use of machinery, planting and harvesting activities, labour requirements, fertiliser use, crop rotation, irrigation and other crop related activities12. These are currently covered by an external crop model, SPACSYS, which generates crop yields, crop rotation and grass yield under a pre-set farm management practices. These crop parameters are used in ScotFarm. The SPACSYS model and its linkages to ScotFarm are described below.

Only the main crops that are available in farm data are included in ScotFarm, however, new crops can be introduced into the system if relevant data (such as yield, gross margin etc.) are available. All

12 Work is undergoing to include crop management practices as well as crop rotation into the ScotFarm.
crop area is initialised to farm level data and a crop area for a particular year must maintain at least 50% of previous year area. The model assumes that all activities are contracted out and contract costs included in variable costs. If a livestock farm has area under cereal production then it is assumed that all cereal produced is fed to the animal (as whole grain) if the farm data do not show revenue collected from crop production for that farm. Farm decision making on crop area is based on crop yields, gross margins and crop area in the previous year.

![Diagram of crop module](image)

**Figure 4: The crop module**

**Data initialisation**

Crop area \( (\text{acrop}) \) under all crops in year one is initialised to the area under crops in farm level data \( (\text{CROPINI}) \). To adjust for a smooth transition of crop area, land area under each crop must be at least 50% of the land area under that crop in the subsequent year. Total land area under all crops \( (\text{aland}) \) should be equal to arable land available on farm.

\[
(\text{f,c,'y1'}) = \sum \text{CROPINI}(\text{f,c}) \\
\text{acrop}(\text{f,c,y}) \geq \sum \text{acrop}(\text{f,c,y-1}) \times 0.5 \\
\text{aland}(\text{f,y}) = \sum \text{acrop}(\text{f,c,y})
\]
Additional constraint is placed to restrict particular crop area not be more than 5 times (an arbitrary threshold) than initial area at any year.

$$acrop(f,c,y) \leq \sum CROPINI(f,c) \times 5$$

SPACSYS\(^{13}\) (Davide Tarsitino)

SPACSYS is a dynamic deterministic model which operates on a daily time step at field scale. It represents the soil profile using a multi layers approach which enables it to account for water and soil nutrients movements. It comprises five interconnected sub-models; plant, soil C, soil N, weather and soil temperature. In addition several management practices can be simulated (e.g. grazing, ploughing, organic/mineral fertiliser application etc.). It has been previously validated for plant growth (Bingham end Wu, 2011) and soil N and C dynamics (Zhang et al 2016).

![A schematic diagram of SPACSYS](https://www.soil-modeling.org/test_models/model-descriptions/syspac)

**Figure 5:** A schematic diagram of SPACSYS

*Source: (Wu el. al., 2007)*

**Model linkage**

**Soft link**

The soft link between SPACSYS and ScotFarm is achieved by feeding crop outputs from SPACSYS such as crop and grass yields and crop rotation to be used in ScotFarm directly. For this the assumption behind both of the model needs to be consistent as much as possible such as use of fertiliser,

\(^{13}\) A more detail description is available @ [https://www.soil-modeling.org/test_models/model-descriptions/syspac](https://www.soil-modeling.org/test_models/model-descriptions/syspac)
stocking density, crops in rotation, grazing pattern, silage cuts, soil type and location of the modelled farm.

Emulator link (supported by BIOSS, University of Edinburgh)
The hard linkage of the two models is achieved by using an emulator (XXX). The emulator is a statistical tool that has been developed at the BIOSS, University of Edinburgh. The emulator takes on outputs from both SPACSYS and ScotFarm under a set of pre-conditioned scenarios and generates model outputs based on these two sets of outputs for optional scenarios (Figure 6). This linkage can run a number of analyses in a short span of time so is useful in saving modelling time and also to test new scenarios.

Farm resources

Land
Total agricultural land is assumed to be fixed in the model. However, this assumption can be removed to allow land transaction by adding renting/letting or selling/buying land activity. For that, one condition needs to put in place that if a farm is renting in then there must be a farm letting out land. Total agricultural land \( t_{land} \) is made up of arable land \( a_{land} \), grassland – permanent/temporary \( g_{land} \) and rough grazing land \( R_{G\_land} \).

\[
t_{land}(f,y) = a_{land}(f,y) + g_{land}(f,y) + R_{G\_land}(f)
\]

Grassland consists of grassland used for grazing \( g_{fland} \), for grass silage \( g_{sland} \) and hay \( g_{hland} \). It is assumed that farmers can reallocate land to grazing or silage/hay production based on feed requirement for animals on farms.

\[
g_{land}(f,y) = g_{fland}(f,y) + g_{sland}(f,y) + g_{hland}(f,y)
\]

Grassland is used to put in stocking rate (STR) constraint on total number of animal on a farm. The stocking rate on each farm is fixed to the existing data inputs assuming that all farms were operating.
under optimum stocking rate. Two rates STR on temporary and permanent grassland and STR2 on rough grazing land are used to differentiate land capabilities.

\[ \text{totani}(f,a,y) \times \text{LU}(a) \leq (\text{gland}(f,y)) \times \text{STR}(f) + \text{RG}_{-\text{land}}(f) \times \text{STR2}(f) \]

**Land transaction**

Farms are allowed to rent in and let out land if that activity is possible. Under such case, additional land variables rent land \((r_{\text{land}})\) let land \((l_{\text{land}})\).

\[ t_{\text{land}}(f,y) = a_{\text{land}}(f,y) + g_{\text{land}}(f,y) + \text{RG}_{-\text{land}}(f) + r_{\text{land}}(f) - l_{\text{land}}(f) \]

This constraint, however, works better if total accumulated land area is used at a regional level \((\text{Reg}_{-\text{land}})\). A farm under that condition can only rent in land if other farms in the region are letting their land out.

\[ \text{Reg}_{-\text{land}}('y') = \text{FARMLAND}(f) \]

\[ \text{Reg}_{-\text{land}}(y) = \sum t_{\text{land}}(f,y) + \sum r_{\text{land}}(f) - \sum l_{\text{land}}(f) \]

**Labour**

It is assumed that all labour used in the model is skilled labour. Labour requirement \((\text{LAB})\) for each of the farm activity is taken from literature (such as Farm Management Handbook). Total labour hour \((t_{\text{lab}})\) is determined by first using family labour \((f_{\text{lab}})\) and only if additional labour is required, labour is hired \((h_{\text{irelab}})\). Total labour hour available on farm is based on assumption that 1 Man Unit provides ‘2200 hours’ of labour on farm annually. \(\text{LAB}_{-\text{cost}}\) is the minimum agricultural wage per hour.

\[ \text{livlab}(f,a,y) = \text{totani}(f,a,y) \times \text{LAB}(a) \]

\[ t_{\text{lab}}(f,y) = \text{livlab}(f,a,y) \]

\[ t_{\text{lab}}(f,y) \leq f_{\text{lab}}(f) \times 2200 + h_{\text{irelab}}(f,y) \]

\[ t_{\text{lab}}\text{cost}(f,y) = h_{\text{irelab}}(f,y) \times \text{LAB}_{-\text{cost}} \]

**Feed**

A feed module was developed in Excel and calculates weight gain of an animal each day based on Brody growth function (Kaps et al., 2000) as follows;

\[ W_{t}(t) = A - (A - W_{t0})e^{-kt} \]
Where, $W_t$ is weight at given time $t$ in days; $W_{t0}$ is the weight at birth; $A$ is the mature weight; $k$ is the maturing rate index.

Energy and protein requirements for individual animal each day for maintenance, growth, pregnancy and lactation are then determined based on Alderman & Cottrill (1993).

For example total energy requirement ($T_o$) is calculated as follows:

$$T_o = M_o + G_o + P_o + L_o \quad \forall \ t$$

Where, $M_o$ = energy requirement for maintenance; $G_o$ = energy requirement for growth; $P_o$ = energy requirement for pregnancy and $L_o$ = energy requirement for lactation.

Each of the components in above equation is determined separately for example, energy requirement for maintenance is determined as follows;

$$M_o = (F + A)/k_m$$

Where, $F$ = fasting allowance; $A$ = activity allowance and $k_m$ = efficiency coefficient for maintenance.

Besides energy and protein requirements, dry matter intake (DMI) by individual animals is also determined in the module based on weight gain and metabolisabilty of a feed. This provides a...
constraint on the voluntary feed intake by an animal. A snippet of the module in excel is provided above (Figure 6).

Feeds available to the livestock on farm are taken from existing farm data which includes fresh grass, grass silage, hay (maize silage), concentrate, whole grains and others. Dry matter function, energy and protein contents for each of the feed are taken from literature. An example of the feed content is provided in Table 1.

Table 1: Feed contents

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (kg/kg)</th>
<th>Energy (MJ/kg)</th>
<th>Protein (kg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh grass</td>
<td>1</td>
<td>11.2</td>
<td>0.16</td>
</tr>
<tr>
<td>Grass silage</td>
<td>1</td>
<td>10.6</td>
<td>0.13</td>
</tr>
<tr>
<td>Concentrate</td>
<td>0.86</td>
<td>15</td>
<td>0.36</td>
</tr>
<tr>
<td>Hay</td>
<td>0.85</td>
<td>8.6</td>
<td>0.09</td>
</tr>
<tr>
<td>Whole grain</td>
<td>0.86</td>
<td>13.8</td>
<td>0.13</td>
</tr>
<tr>
<td>Maize silage</td>
<td>0.29</td>
<td>11.3</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Feed system**

The feed system in the model uses all available feed at first and brings in bought feed when required. Total number of animal that can be kept on farm is constrained under their requirements of energy (ENREQ), protein (PREQ), feed intake (DMI) and availability of total feed (mfeed) that fulfil those requirements.

\[
totani(f,a,y) \cdot \text{ENREQ}(a,m) \leq \sum mfeed(f,a,y,m,b) \cdot \text{ENFEED}(b)\\
totani(f,a,y) \cdot \text{PREQ}(a,m) \leq \sum mfeed(f,a,y,m,b) \cdot \text{PRFEED}(b)\\
totani(f,a,y) \cdot \text{DMI}(a,m) \leq \sum mfeed(f,a,y,m,b) \cdot \text{DMFRAC}(b)\\
\]

All available feed is determined by the land to produce that feed and specific yield for a particular farm. Yield for fresh grass, grass silage and hay are taken from SPACSYS which uses farm data (stocking rate, location and soil type) to simulate these feed yields. A grass switch (GRASS_SWT) is used to allow grazing on field (based on a threshold grass quantity (0.5 t/ha) available on field. This switch ensures the minimum amount of grass required on land for grazing. It is assumed that once silage is cut (based on 1-, 2- and 3-cut options), land under silage production can be used for grazing. A silage switch (GSILAGE_SWT) is used to control grazing option on silage land. SPACSYS do not consider rough grazing conditions for grass growth simulation, hence, it is assumed that rough grazing can produce around 30% of grass growth in a temporary/permanent grassland. Besides on-farm production of grass silage, farms are also allowed to buy grass silage from market if necessary.

\[
\sum mfeed(f,a,y,m,\text{"fg"}) \leq gfland(f,y) \cdot \text{GRASS_YIELD}(m) \cdot \text{GRASS_SWT}(m) + gsland(f,y) \cdot \text{GRASS_YIELD}(m) \cdot \text{GSILAGE_SWT}(m) + RGRAZ(f) \cdot \text{GRASS_YIELD}(m) \cdot \text{GRASS_SWT}(m) \cdot 0.3;\\
\sum mfeed(f,a,y,m,\text{"hay"}) \leq ghland(f,y) \cdot \text{HAYYIELD};
\]
The compound feed in the model comes from two sources, on-farm produced feed crop \( \text{acrop}_{fc} \) which is mostly cereal used as ‘whole grain feed’ and concentrates bought from the market. There is a minimum (or/and maximum) allotment of concentrate feed used on a farm that is controlled by ‘CONCUSE’ for each animal category.

\[
\sum \text{mfeed}(f,a,y,m,\text{"gsil"}) \leq \text{gsland}(f,y) \times \text{SILAGE\_YIELD}(m) \times 1000 + \text{buysil}(f,y,m);
\]

\[
\sum \text{mfeed}(f,a,y,m,\text{"conc"}) \geq \text{totani}(f,a,y) \times \text{CONCUSE}(a);
\]

\[
\sum \text{mfeed}(f,a,y,m,\text{"grain"}) \leq \sum (\text{acrop}(f,fc,y) \times \text{CROP\_YIELD}(fc)) ;
\]

**Price projections**

There are two sources from where prices are gathered: i) Farm survey data and ii) market data. To account for a possible impact of future commodity prices, price projections were used to represent price changes over the model time frame. The price projections are taken from external partial equilibrium (PE) model namely FAPRI\(^{14}\) model. The requirement is that the conditions and assumption behind the scenarios used for the price projection needs to be similar to the conditions and assumption in ScotFarm. An example is provided in Figure 7 below, which provides the FAPRI-UK price projections (index 2010 prices) for different agricultural commodities in the UK. The price projections are used as indices and included in ScotFarm to generate revenue and cost of each production activities.

![Figure 7: The FAPRI-UK price projections for different agricultural commodities (index to 2010 prices)](https://www.afbini.gov.uk/publications/fapri-uk-baseline-projections-2015)

---

\(^{14}\) For details please see http://www.fapri.iastate.edu/models/

\(^{15}\) https://www.afbini.gov.uk/publications/fapri-uk-baseline-projections-2015
Farm margins

The model can produce farm gross margins or net margins based on data availability and requirement of specific margins for a study. Farm margin for each of the production system is determined separately. For example, dairy margins (\text{DairyM}) is the summation of total revenues from milk sell, male calf sell and culled dairy animals minus replacement costs, variable costs and feed costs. The price indices (‘DI’, ‘BI’, ‘SI’, ‘VID’, ‘VIB’ and ‘SIB’) are taken from a PE model as described above. The coupled farm payments are linked with respective production activities and added to the production margins. For instance for Scottish livestock farms, Voluntary Calf Payment Scheme (\text{VCS_calf}) and Voluntary Ewe Payment Scheme (\text{VCS_ewe}) are added while determining the Beef and Sheep margins.

\textbf{Dairy margin}

\[
\text{DairyM} = \text{totmilk}(f, y) \times \text{MILKPrice}(f) \times \text{MI}(y) + \text{sellmcalf}(f, y) \times \text{CALFPrice}(f) \times \text{DI}(y) + \text{culldairy}(f, y) \times \text{DAIRYPrice}(f) \times \text{DI}(y) - \text{buyheif}(f, y) \times \text{HEIFPrice}(f) \times \text{DI}(y) - \sum \text{totani}(f, \text{ads}, y) \times \text{LU(ads)} \times (\text{VARCosts}(f) \times \text{VID}(y)) - \sum (\text{mfeed}(f, \text{ads}, y, m, "conc") \times \text{CONCPrice} \times 0.001 \times \text{CI}(y)) + \text{mfeed}(f, \text{ads}, y, m, "gsil") \times \text{SILAGE_Price})
\]

\textbf{Beef margin}

\[
\text{BeefM} = \text{sellcalf}(f, y) \times \text{CALFPrice}(f) \times \text{BI}(y) + \text{sellbeef1}(f, y) \times \text{BEEF1Price}(f) \times \text{BI}(y) + \text{sellbeef2}(f, y) \times \text{BEEF2Price}(f) \times \text{BI}(y) + \text{cullsuck}(f, y) \times \text{CULLPrice}(f) \times \text{BI}(y) - \text{buycalf}(f, y) \times \text{ANI}(f, ‘asc6’) \times \text{CALFPrice}(f) \times \text{BI}(y) - \text{buysuck}(f, y) \times \text{ANI}(f, ‘asc’) \times \text{SUCKPrice}(f) \times \text{BI}(y) - \text{buybeef1}(f, y) \times \text{ANI}(f, ‘abl’) \times \text{BEEF1Price}(f) \times \text{BI}(y) - \sum \text{totani}(f, \text{ab}, y) \times (\text{VARCosts}(f) \times \text{VIB}(y) \times \text{LU(ab)))} - \text{totani}(f, \text{ab}, y) \times \text{OH} \sum (\text{mfeed}(f, \text{ab}, y, m, ‘conc’) \times \text{CONCPrice} \times 0.001 \times \text{CI}(y)) + \text{totani}(f, ‘asc6’, y) \times \text{VCS_calf}
\]

\textbf{Sheep margin}

\[
\text{SheepM} = \text{selllamb}(f, y) \times \text{LAMBPrice}(f) \times \text{SI}(y) + \text{sellewe}(f, y) \times \text{EWEPrice}(f) \times \text{SI}(y) - \text{buylamb}(f, y) \times \text{ANI}(f, ‘ae’) \times \text{LAMBPrice}(f) \times \text{SI}(y) - \sum \text{totani}(f, \text{ass}, y) \times \text{LU(ass)} \times 0.05 \times \text{VIS}(y)) - \sum (\text{mfeed}(f, \text{ass}, y, m, ‘conc’) \times \text{CONCPrice} \times 0.001 \times \text{CI}(y)) + \text{totani}(f, ‘ae’, y) \times \text{VCS_ewe}
\]

\textbf{Crop margin}

\[
\text{CropM} = \sum \text{acrop}(f, c, y) \times \text{CROPGM}(c) \times \text{CrI}(c, y))
\]
Farm profits (Objective Function)
The model maximises farm profits which is the sum of margins from farm activities, subsidy payments (Basic Payment Scheme (BSP) and Area of Natural Constraint payments (LFAS) minus labour costs (tlabcost), feed production costs (GCosts, SCosts and HCosts) and overhead costs (OHCosts). The decoupled farm subsidies (BPS\textsuperscript{16} and LFAS) are added to total farm margin. The fixed costs (OHCosts) can be used in the objective function if farm net margins are to be examined.

\[
Tfgm = \text{DairyM} + \text{BeefM} + \text{SheepM} + \text{CropM} + \text{BSP} + \text{LFAS} - \text{tlabcost} - \text{buysil} \times \text{SILAGEPrice} - \text{gfland} \times \text{GCosts} - \text{gsland} \times \text{SCosts} - \text{ghland} \times \text{HCosts} \quad ( - \text{OHCosts})
\]

This set up of the objective function maximises the individual farm margins over the time frame of the model runs. The farms are not linked with each other hence all farms would have individual margins regardless of farm activities chosen by individual farms. The farms can be linked together with interacting activities between farms such as land transactions, herd movements (replacements, buying and selling activities), farm resource exchanges (feed, machinery, manure/slurry). These interacting activities can be restricted at a regional or national level. With these activities, farm margins optimisation of any single farm will rely on farm activities on other farms. For example, a profiting farm can expand its production activity and maximise its profits by acquiring more land. But this is only possible if there are other farms selling their land.

\textsuperscript{16} BSP is linked with farm land by using the rates of farm payment (region1, region2 and region 3 rates) under the categories of land available on farms. This is calculated at pre-modelling stage and the calculated payments for each farm are then included in the model.
### Appendix

Table A1: Subscripts used in the model

<table>
<thead>
<tr>
<th>index</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>f</td>
<td>farms</td>
</tr>
<tr>
<td>y</td>
<td>years</td>
</tr>
<tr>
<td>m</td>
<td>months</td>
</tr>
<tr>
<td>a</td>
<td>livestock category</td>
</tr>
<tr>
<td>‘asc’</td>
<td>suckler</td>
</tr>
<tr>
<td>‘ac’</td>
<td>calf</td>
</tr>
<tr>
<td>‘ah’</td>
<td>heifer</td>
</tr>
<tr>
<td>‘ad’</td>
<td>dairy</td>
</tr>
<tr>
<td>‘asc6’</td>
<td>beef calf</td>
</tr>
<tr>
<td>‘ab1’</td>
<td>1 year old beef</td>
</tr>
<tr>
<td>‘ab2’</td>
<td>2 year old beef</td>
</tr>
<tr>
<td>‘al’</td>
<td>lamb</td>
</tr>
<tr>
<td>‘ae’</td>
<td>ewe</td>
</tr>
<tr>
<td>c</td>
<td>crops</td>
</tr>
<tr>
<td>b</td>
<td>feed</td>
</tr>
<tr>
<td>‘fg’</td>
<td>fresh grass (grazing)</td>
</tr>
<tr>
<td>‘gsil’</td>
<td>grass silage</td>
</tr>
<tr>
<td>‘hay’</td>
<td>hay</td>
</tr>
<tr>
<td>‘conc’</td>
<td>concentrate</td>
</tr>
<tr>
<td>‘grain’</td>
<td>whole grain feed produced on farm</td>
</tr>
</tbody>
</table>
References


